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# Experimental Investigation on Leachate-Contaminated Lateratic Soil

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## ABSTRACT

Contamination of soil due to the Leachate from Municipal Solid waste is a major environmental problem. Landfill leachate is generated from liquids existing in the waste as it enters a landfill or from rainwater that passes through the waste within the facility. A large quantity of Leachate is produced from the dump yards in various parts of India. With urban development and expansion, these areas are reclaimed for construction and other purposes. The engineering behaviour of structures constructed of/with municipal solid waste fills are unpredictable. An extensive laboratory exploration was carried out to determine the index properties, shear strength characteristics, compaction characteristics and hydraulic conductivity of clean and contaminated lateritic soil. Contaminated samples are prepared by mixing the lateritic soil with varying amount of leachate content like 20%, 40%, 60%, 80% and 100% by weight to vary the degree of contamination. The effects of leachate on the Atterberg's limit showed decrease in liquid and plastic limit values with the increase in the leachate content. Reduction in maximum dry density and increase in hydraulic conductivity were observed.

**Keywords** : Leachate, Residual Soil, Atterberg's Limit, Shear Strength.

## I. INTRODUCTION

A landfill is an engineered pit, in which layers of solid waste are filled, compacted and covered for final disposal. It is the "simplest, cheapest and most cost effective method of disposing waste" in several parts of the world. Despite these benefits, leachate is a threat to the environment due to the presence of toxic inorganic and organic constituents in the leachate. Leachate is produced in landfill sites through hydrolysis processes (products of biochemical changes in organic substances) or is the result of water penetration. It is composed of large amounts of both organic and inorganic compounds, and their concentration depends to the age of a landfill site. Leachate from an improperly constructed landfill results an extensive contamination of soil beneath and adjacent to the dumping area. Leachate from the solid waste dump has a significant effect on the chemical properties as well as the geotechnical properties of the soil. Leachate can modify the soil properties and significantly alter the behaviour of soil. Laterite soil is one of the important soil groups of Kerala. Large areas of land with lateritic soil are currently used for open dumping of municipal solid waste. This paper presents the results of a laboratory testing program carried out to determine the effect of leachate contamination for a period of 15 days on the geotechnical characteristics (consistency limits, compaction characteristics, hydraulic conductivity and shear strength) of lateritic soils.

## Experimental Investigation

### *Study Area*

The study area is located in Brahmapuram, a small village in Kochi, Kerala, India which spans across 106 acres. The volume of waste being dumped at the dump yard was 250 tonnes/day. Various waste materials such as domestic waste, e.g. Kitchen waste; plastic, paper, glass, cardboard, cloths etc. are dumped at this site. Construction and demolition waste like bricks, blocks, timber, are also dumped. Poultry market, fish market, slaughterhouse, dairy farm and non-infectious hospital waste is also dumped. The site is a Non-engineered low lying open dump, a huge heap of waste up to a height of 20 m. The main problem here is the contamination in the surface water bodies and the soil.

Soil samples were collected by removing the surface debris and subsurface soil dug to a depth of about 30cm and 1m with a hand auger.

50 Kg of soil sample was taken for analyzing soil chemical properties, soil consistency limits such as liquid limit, plastic limit, shrinkage limit, plasticity index, specific gravity, compaction characteristics, hydraulic conductivity and shear strength of soil in the laboratory. The geotechnical properties of the soil are given in Table I.

TABLE I . GEOTECHNICAL PROPERTIES OF THE SAMPLE SOIL.

| **Properties** | **values** |
|---|---|
| Specific Gravity | 2.62 |
| Liquid Limit,% | 35 |
| Plastic Limit,% | 21 |
| Maximum dry density (g/cc) | 2.25 |
| Optimum Moisture Content (%) | 12.5 |
| Permeability(k) | $2.7 \times 10^{-5}$ |
| | |
| Gravel (%) | 2 |
| Sand (%) | 62 |
| Silt (%) | 22 |
| Clay (%) | 12 |

The chemical characteristics of the laterite soil was examined and the results obtained are shown in Table II.

TABLE II . CHEMICAL CHARACTERISTICS OF THE SAMPLE SOIL.

| **Properties** | **values** |
|---|---|
| pH | 4.5 |
| $CaCO_3$ (%) | 2.75 |
| OM of soil (%) | 0.58 |
| $SO_4 \times 10^{-3}$ (%) | 4 |
| $Fe_2O_3$ (%) | 8.2 |
| $SiO_2$ (%) | 72 |
| $Al_2O_3$ (%) | 45 |

$CaCO_3$ - Calcium carbonate; OM - Organic matter; SO4 - Soluble sulphate; $Fe_2O_3$ - Iron content; $SiO_2$ - Silica; $Al_2O_3$ - Alumina content

### *Leachate*

Leachate used in this study was collected from Brahmapuram Biogas Plant, Ernakulum, Kerala. The characteristics of leachate are given in the Table III. The alkalinity, pH value and the cation content are very significant parameters that affect the properties of the soil.

TABLE III . COMPOSITION OF THE LEACHATE

| **Parameter** | **Maximum concentration in (mg/L)** |
|---|---|
| COD | 285 |
| Total Dissolved solids | 2359 |
| Total hardness | 170 |
| pH | 6.1 |
| sulphate | Trace |
| chloride | 2136 |
| calcium | 50 |

| | |
|---|---|
| sodium | 250 |
| potassium | 420 |

Chemical analysis was carried out based on the standard methods published by American Public Health Association.

*Test Programme*

Laboratory tests were conducted to determine the index properties, compaction characteristics and hydraulic conductivity of clean and contaminated lateritic soil. Contaminated samples are prepared by mixing the lateritic soil with varying amount of leachate content like 20%, 40%, 60%, 80% and 100% by weight to vary the degree of contamination. The samples were tested after a curing period of 15 days. The test samples were preserved in air tight packets to ensure proper reaction between the soil and leachate.

**Results and Discussions**

*Effect of Leachate on Atterberg's limits*

The Atterberg's limit is used to identify the soil water content that is related to the behavior of the soil. The liquid limit, *wL* of leachate mixed soil indicated the decreasing in value from 35 % to 18 % with the increase of leachate contents between 0% and 100%. The differences in the decrease in liquid limit value were higher than the plastic limit.

Lateritic soil contains more of kaolinite mineral having low shrink–swell capacity and a low cation exchange capacity. Unlike, montmorillonite mineral, the effect of diffused double layer is negligible in kaolinite.

However, the Liquid limit behavior which depends on the diffused layer was found to decrease in laterite soil, even though the presence of kaolinite mineral was more. As the amount of leachate increases, the water content will reduce and the chance to react with soil particles will eventually drop. The leachate is more acidic in nature which results in reduction of liquid limit due to increase in concentration of electrolyte of the pore fluid and therefore, decreases the thickness of diffused double layer.

The variation of liquid limit with different percentages of leachate in shown in Fig 1.

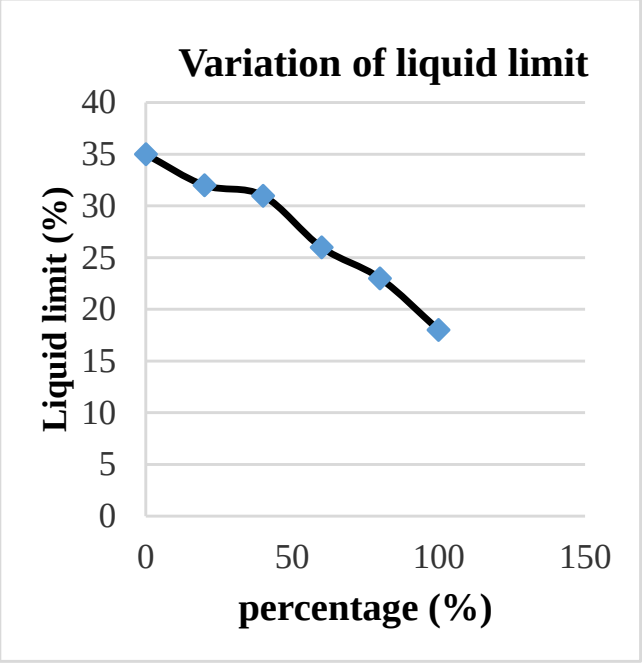


Fig 1. Variation of Liquid limit

*Effect of Leachate on Compaction characteristics of soil*

The soil sample was mixed with the leachate and allowed for curing for about 15 days and the Standard Proctor compaction tests were carried. The results are plotted in Fig.2, in the form of dry density versus water content curves.

The maximum dry density of the laterite soil decreases with increasing concentration of leachate and optimum moisture content increases with increasing concentration of leachate. This is mainly due to the chemical reaction between the minerals present in the soil and the compounds present in the leachate.

The presence of chemicals in leachate, changes the structure of pore fluid in soil, thereby affecting the properties of soil. Maximum reaction occurred at a

leachate concentration of 60%, beyond which the soil properties were not affected.

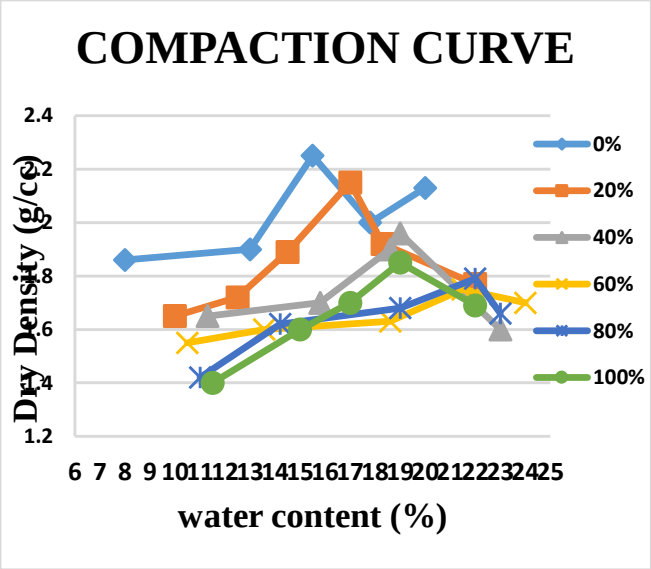


Fig 2. Variation of Comapction characteristics

### *Effect of Leachate on Hydraulic Conductivity of soil*

*Falling head permeability tests were conducted on samples cured with varying concentration of leachate for 15 days. The hydraulic conductivity was found to increase with increase in leachate content (Fig. 3). This increase in hydraulic conductivity of the soil was due to chemical reaction between the leachate and the clay minerals present in lateritic soil. The acidic leachate can dissolve clay minerals increasing the pore space in soil and hence the hydraulic conductivity increases.*

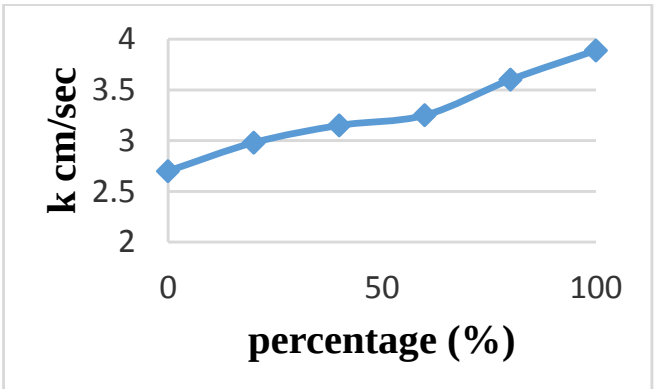


Fig 3. Effect of Chemicals on Permeability in $10^{-5}$ cm/s

### *Effect of Leachate on Shear Strength of soil*

Soil samples compacted at Maximum dry density and Optimum moisture content were used to find the shear parameters of soil samples mixed with leachate. Consolidated Undrained triaxial test was conducted on samples after saturated and prior application of back pressure. The results are shown in Table IV.

The cohesion of soil was found to increase slightly and the internal friction decreased. The leachate has increased the bonding between the particles by altering the chemical composition such that the soil behaved more like a clay having more of cohesion and less of shearing resistance.

TABLE III . SHEAR STRENGTH OF LATERITIC SOIL MIXED WITH LEACHATE

| Sample | Cohesion (c') kN/m² | Angle of internal friction (φ') |
|---|---|---|
| Soil | 18.2 | 31 |
| Soil + 20% Leachate | 20 | 26 |
| Soil + 40% Leachate | 24.6 | 22 |
| Soil + 60% Leachate | 27.3 | 16 |
| Soil + 80% Leachate | 27.8 | 15 |
| Soil + 100% Leachate | 28.5 | 13 |

## Conclusion

The experimental investigations gave an insight to the effect of leachate on the geotechnical properties of laterite soil. The liquid limit and plasticity index decrease with an increase in the percentage of leachate. This decrease in the Atterberg's limits are due to the predominant influence of the increased electrolyte concentration and organic chemicals present in the leachate on the

diffuse double layer thickness of soil. Leachate contamination leads to increase the hydraulic conductivity of the soil tested. This is attributed due to the chemical reactions with the leachate and the soil particles. Highly acidic or basic leachate can have significant effect on the index and engineering properties of the soil. Experimental results indicated that with the increase in percentage of leachate, maximum dry density decreased from an initial value of 2.25g/cm$^3$ to 1.75 g/cm$^3$ and optimum moisture content increased to 22% from an initial value of 12.5 % when the soil was mixed with 60% leachate by weight. Beyond which no significant change was observed. The cohesion of the laterite soil increased and the shearing resistance decreased with increase in Leachate concentration. This variation is attributed to the chemical reaction between the soil and the leachate, resulting in soil to behave more like clay.

Based on this study, the presence of leachate fluid in the soil brings negatives impact to the geotechnical properties of Lateritic-clayey soil. Soil-leachate contamination must be recovered before any construction is done.

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